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(54) Laser coagulation of the retina

(57) In an apparatus for treating the layers of the retina below the fundus of the eye 2, the degree of coagulation caused at a striking point by treatment laser 1 is monitored by projecting a measuring beam at the vicinity of the striking point and detecting 7 light reflected or scattered from the retina or fluorescence caused by the measuring beam. A refraction device 5 allows the striking point of the treatment beam on the fundus to be changed.

The measuring beam may be provided by a second radiation source (8,fig 2) or may be obtained by switching and/or filtering the treatment laser 1.

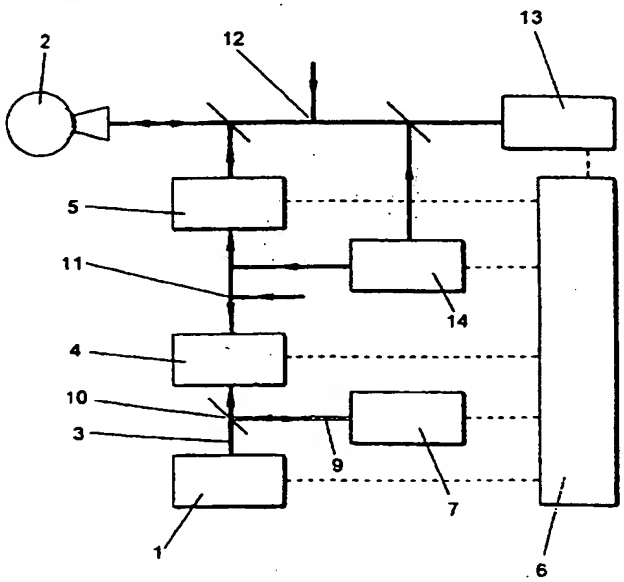

Fig.1

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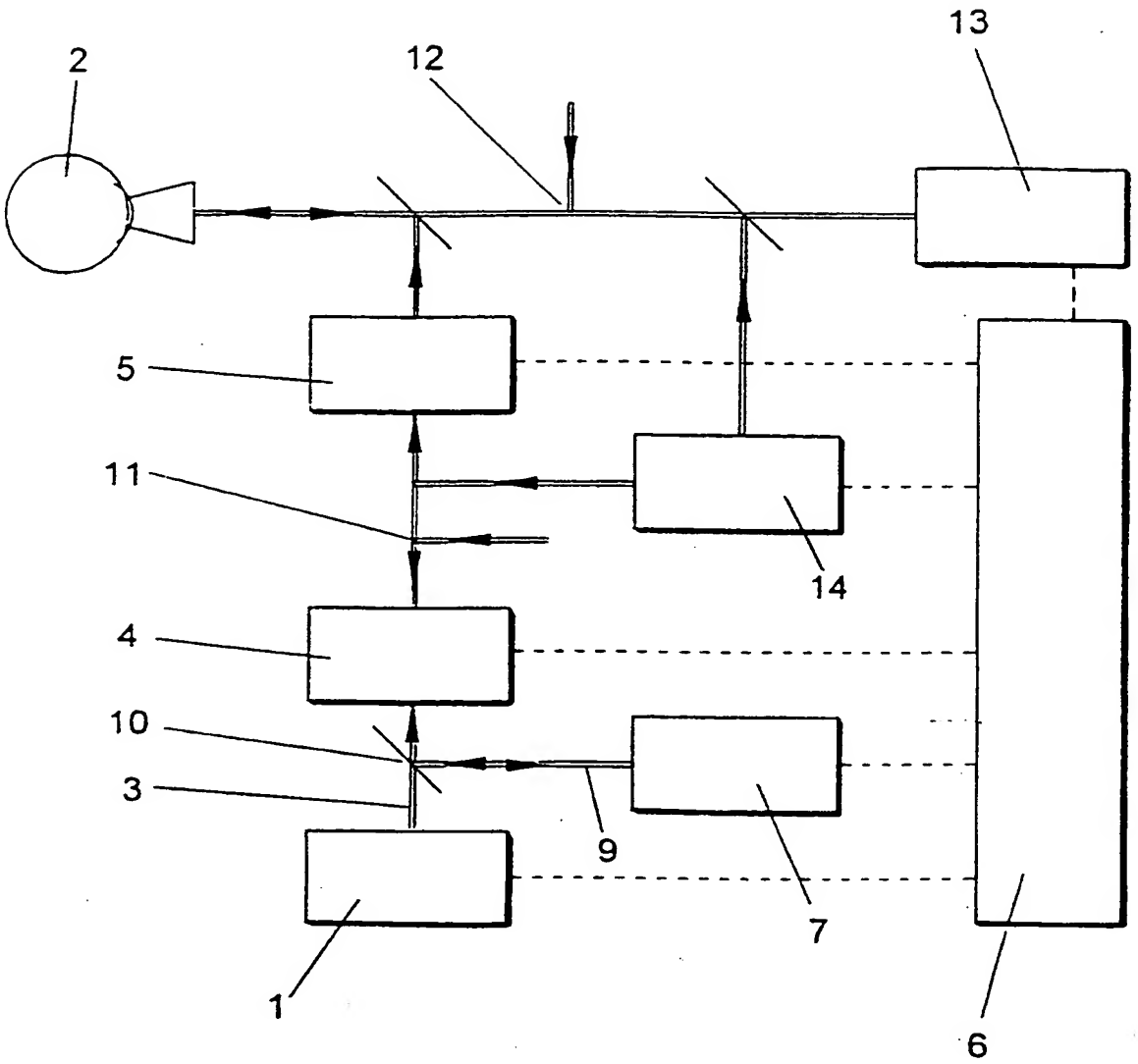

Fig.1

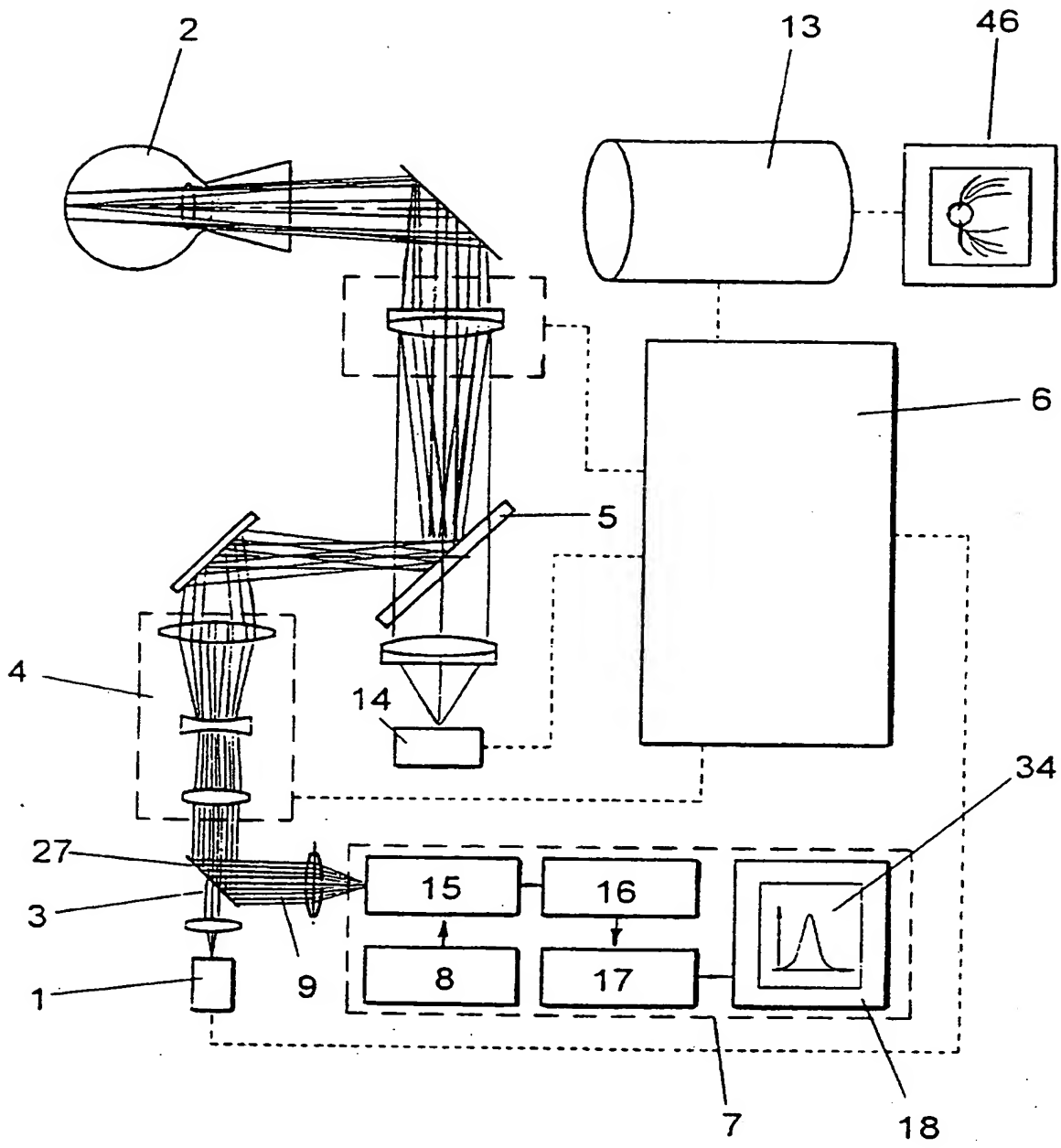

Fig.2

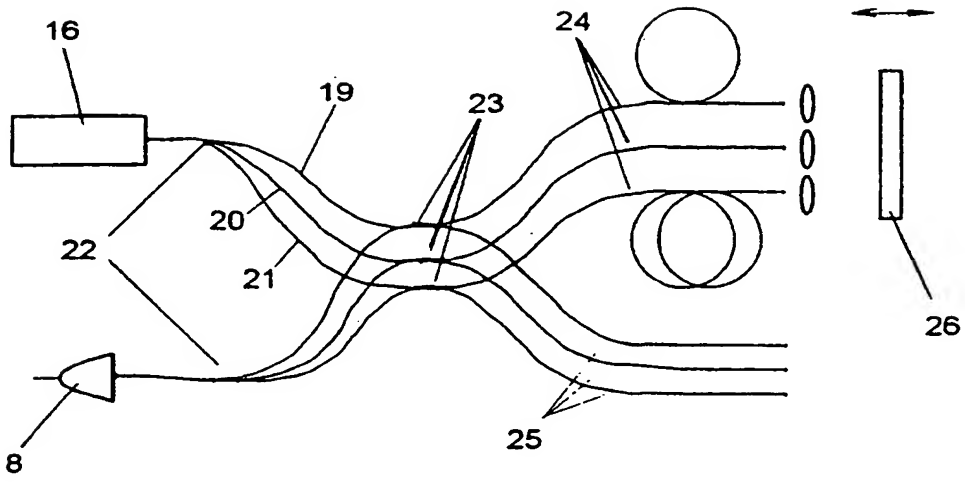

Fig.3

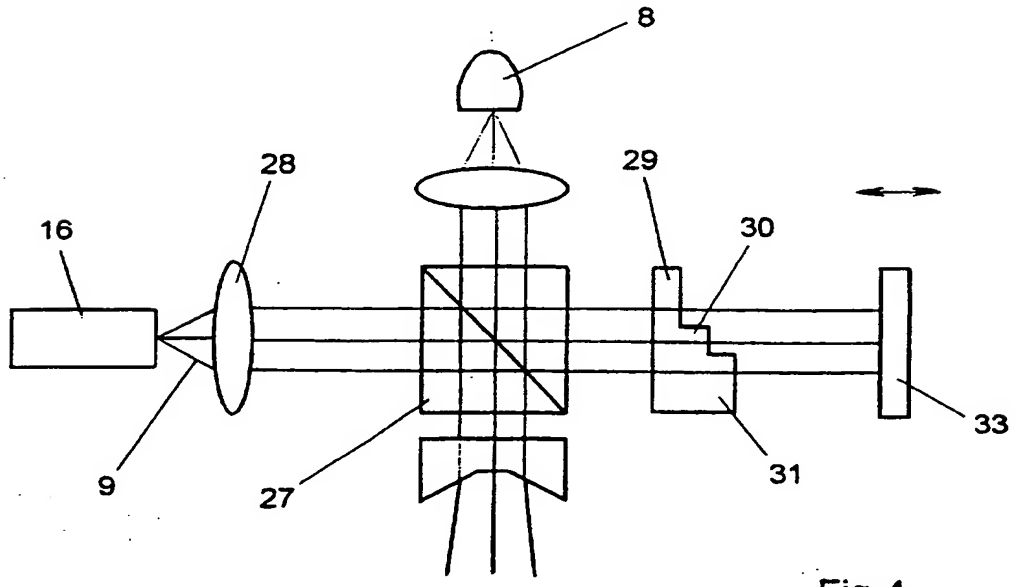

Fig.4

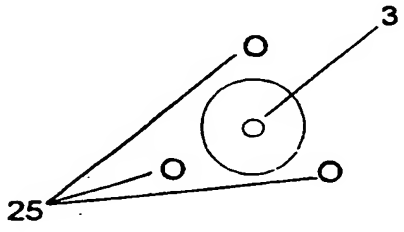

Fig.5

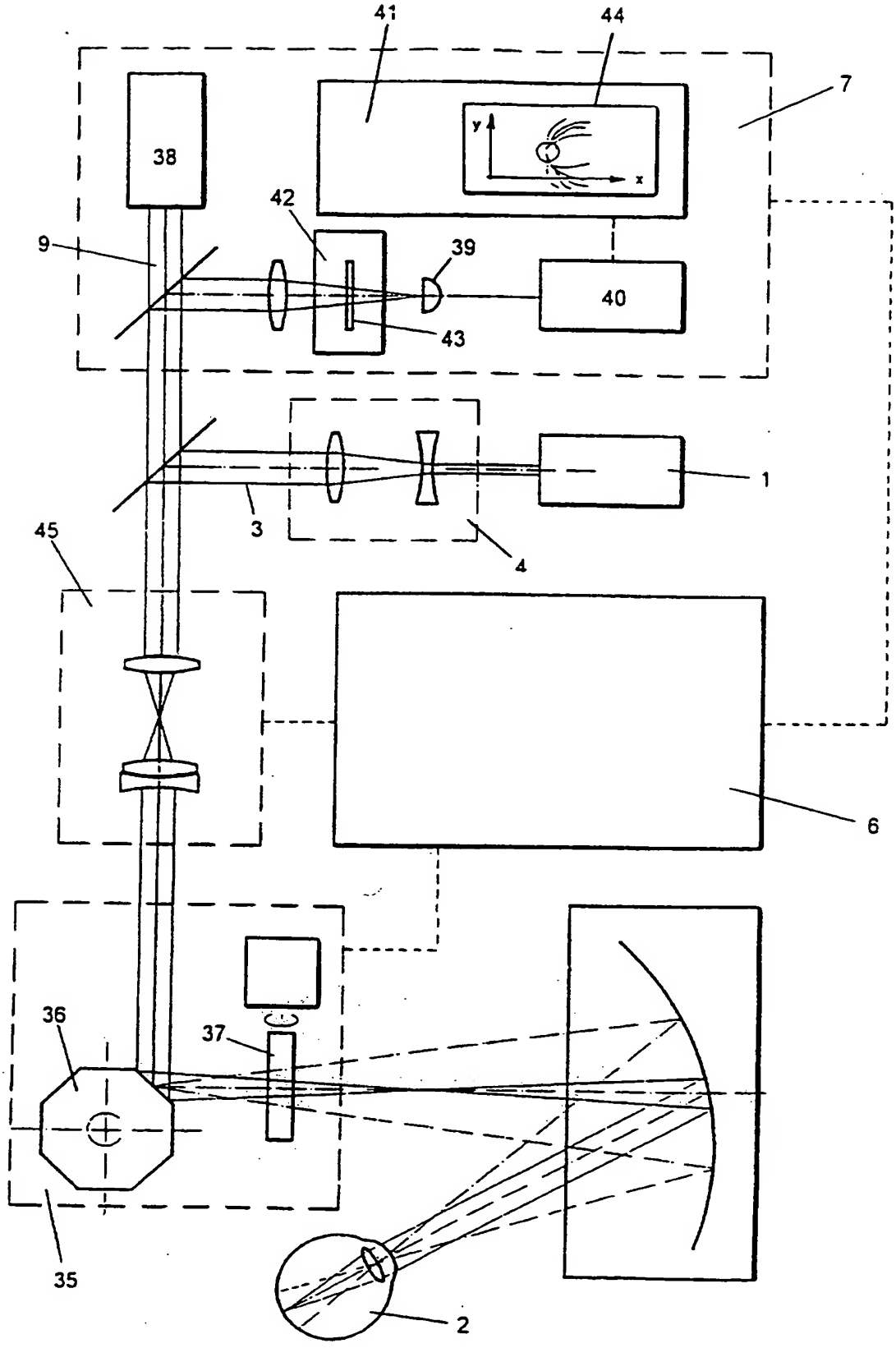

Fig.6

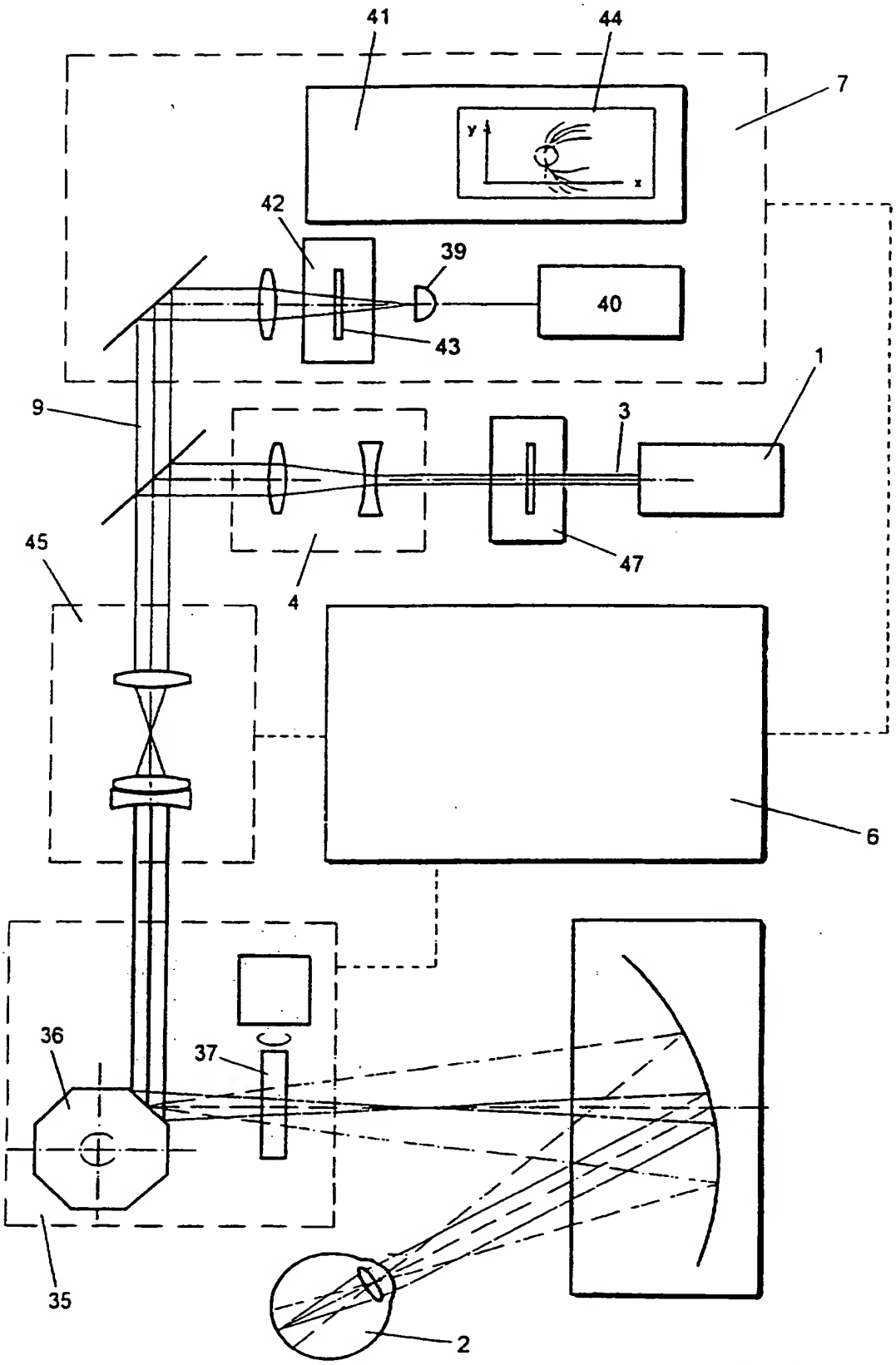

Fig.7

DESCRIPTION

ARRANGEMENT FOR THE LASER COAGULATION OF LAYERS OF RETINA LYING BELOW THE FUNDUS SURFACE AND PROCEDURES FOR OPERATING THIS ARRANGEMENT

The invention relates to an arrangement for the laser coagulation of layers of retina lying below the fundus surface with at least one source of radiation, a refraction device for locally changing the striking point of the beam on the eye fundus and with an operation and control device. The invention further relates to procedures for operating this arrangement.

With laser coagulation on the human eye, the desired therapy effect is achieved by a thermal tissue destruction at selected areas of the eye fundus. To do this, energy is introduced into the tissue in the form of laser light pulses. With pulse durations of 50 to 200 ms and outputs of 200 mW, the irradiated energy is absorbed into the pigment epithelium whereby the surrounding tissue up to the fundus surface heats up locally. Successful coagulation can be recognized from a white colouring (necrosis) at the coagulation point and can be checked by visually observing the eye fundus e.g. by means of a slit-lamp. The end of the treatment is determined by means of observation according to the subjective opinion of the operator. This type of check is described, among others, in DE 3024169 A1.

DE 2829516C2, on the other hand, reveals a surgical laser with a device for recording measured values relating to the results of the thermal effect of the

laser beam on the biological tissue and for gaining a deactivation signal from these measured values when a prescribed treatment state is reached. A sensor device records the thermal radiation from the treated tissue area and from a wider tissue area adjacent to the treatment point and feeds it to an electronic evaluation device. This compares the two values and from the comparison supplies a control signal which triggers the deactivation of the laser or at least an acoustic notification as soon as a prescribed difference value is exceeded. In an alternative embodiment, which is also explained in the cited publication, the signal is gained on the one hand by detection of the backscattered laser light from the irradiated tissue area and on the other by recording the backscattering from a further tissue area occurring because of internal scattering. Further embodiments of this principle have been published in "Lasers in Surgery and Medicine" 1994, 15 (1) p 54-61 and in "Proceedings of SPIE", 1992, 1644, p 217-227.

Common to all these devices is the evaluation of electromagnetic radiation emitted from the fundus surface at the coagulation point and its surroundings, The requirements for the use of these mechanisms for visual or even automatic feed-back checking of successful coagulation is a coagulation effect extending to the surface of the retina which can be recorded by changes in the properties of the surface of the retina.

In a new coagulation procedure the pulse duration for introducing the laser energy to the coagulation point is reduced to microseconds and, in some

cases, to picoseconds and the repetition rate is increased to 50 to 200 Hz. Publications on this can be found in "Lasers in Surgery and Medicine" 1994, 15 (1) p 44-53 ("Intracular microsurgery with a picosecond Nd:YAG laser"). The laser energy deposited in the pigment epithelium or other deep retina layers with this reduced pulse duration means that the heat conduction processes in the surroundings are more negligible. This results in a medical advantage that the coagulation effect on the direct surroundings of the retinal pigment epithelium remains limited and thus damage in particular to the layer of nerve fibres above can be avoided. However, the disadvantage of this is that the coagulation effect on the fundus surface can no longer be recorded opthalmoscopically. Checking the progress of coagulation and an automatic control by detecting the coagulation light backscattered from the fundus surface as described above is therefore no longer possible; the treatment state reached can no longer be checked during coagulation.

The case is similar with photodynamic therapy as a newer method for selectively sealing sub-retinal neovascularisations; publications on this can be found in Ophthalmologe (1994) 91; pages 789-795, Springer-Verlag 1994. Photodynamic therapy uses the systematic administration of a primarily non-toxic photosensitiser with targeted light activation of the pigment by laser intensities below the damage limit. At a light exposure of 10-25 J/cm², a complete sealing of the surface capillary choroid can be achieved without retinal damage. An increase in the dose to 50-100 J/cm² leads both to complete sealing even of

deeper choroidal vessels and an effect on adjacent areas of the retina. The disadvantage here too is that the changes in the deeper layers of the retina can no longer be recorded opthalmoscopically with familiar procedures and arrangements as only changes on the fundus surface can be detected and evaluated. Therefore checking the progress of the photodynamic therapy and automatic control by detecting the light backscattered from the fundus surface as in the new coagulation procedures is not possible.

In EP 0697 611 A2, optical coherence tomography (OCT) is used to display and control laser-induced tissue changes so as to be able to control and check the therapy laser. A beam path for optical coherence tomography is superimposed on a therapy laser so that the coagulation area can be traced with a scanner in order to generate deep section images. The therapy laser and the scanning area are positioned together on the fundus by means of an observation unit. This proposal is suitable for observing the coagulation effect at one prescribed location in deep layers of the retina. The disadvantage with this procedure and the associated arrangement, however, is that it is not possible to locate the coagulation area because the quantity of data to be recorded to observe the entire fundus would be much too large and the necessary measuring time would be much too great.

An object of the present invention is to develop an arrangement of this type for laser coagulation in such a way that objective evidence of the changes in the deeper tissue layers caused by the coagulation is possible during a

coagulation treatment with short laser pulses and that a direct conclusion can be derived from this for aborting or continuing the treatment.

This object is solved in accordance with the present invention with an arrangement of the aforementioned category wherein means for striking the coagulation point and/or its near surroundings with an optical measuring beam during a treatment session are provided and wherein there is at least one measuring device for recording the optical radiation issuing from the point struck. A detector can be provided in the measuring device and an evaluation unit and an information output unit can be connected to the detector. The measuring device may be connected to the operating and control unit.

An advantage obtained with this is that during a coagulation treatment, objective evidence of the changes effected in the tissue layer by the therapy pulses is possible and a direct conclusion can be derived from this for aborting or continuing the treatment.

A particularly advantageous embodiment of the invention provides for a separate radiation source for emitting a measuring beam path directed at the coagulation point and/or its near surroundings, optical modules for coupling and decoupling the measuring beam path to the therapy beam path are provided and a device for simultaneously striking several measuring points staggered in the depth of the tissue and/or located near the coagulation point.

With this it is possible to produce objective evidence of changes which cannot be detected on the surface of the tissue treated, even with treatment with

short laser pulses which may be in the rage of microseconds or picoseconds and to derive direct conclusions for aborting or continuing the treatment with therapy pulses.

It is within the framework of the invention if the source of radiation is designed as a short coherent light source and an interferometer and a detector harmonised to the short coherent light source are provided whereby the interferometer is provided with at least one reference arm of variable length and has at least one measuring arm lying partly in the eye. It is advantageous if the measuring beam path thus generated can be superimposed coaxially on the therapy beam path; a common refraction of the measuring beam path and the therapy beam path to change the striking point on the eye fundus should occur.

The interferometer can be designed as a fibre interferometer in which the number of optical fibres corresponds to the number of measuring points planned, the individual optical fibres in the reference arms are of different lengths and optical fibres of different lengths are allocated to the individual measuring points. The result is that the information issuing from the measuring points must travel along different length optical routes in the reference arms which guarantees temporally staggered detection of the information issuing from the measuring points.

Alternatively to the aforementioned embodiment, the interferometer can have a lens for splitting the measuring beam path into several individual beam paths whereby the number of individual beam paths corresponds to the number

of measuring points planned, the individual beam paths emerge from different points on the lens and sheets of varying thickness are arranged in the reference arms plane-parallel to the individual beam paths with the result that the information issuing from the measuring points must travel along different length optical routes in the reference arms and temporally staggered detection is guaranteed.

It is advantageous if the exit points of the individual beam paths are arranged radially-symmetrically to the therapy beam path; a common refraction of the measuring beam and the therapy beam path to change the striking point on the eye fundus should occur.

The information output unit should have at least one display for indicating the degree of reflection on the fundus.

In a particularly advantageous embodiment at least one source of radiation is provided whose light wavelength incites at least one fluophor occurring naturally or not occurring naturally in the body and there are optical modules for coupling and decoupling the measuring beam path in the therapy beam path, a detector and at least one optical filter which can be arranged in front of the detector. The filter is in tune with the fluorescence wavelength of the fluophor.

The optical filter which can be arranged in front of the detector can be tuned to the autofluorescence wavelength of 512 nm of the body's own fluophor lipofuscin.

A comparison of the received signals with a reference value can provide information on the fluorescence behaviour and/or the autofluorescence behaviour of the tissue. Thus changes in the fluorescence / autofluorescence behaviour as a result of the treatment can be immediately recorded and evaluated.

The information output unit for this case should have at least one display for indicating the colour intensity and/or the reflectance on the fundus.

A common scanning device can be provided for lateral refraction of the measuring beam path and lateral refraction of the therapy beam path, resulting in a simplification of the structure of the arrangement and simpler operability. Thus it is possible to locate the coagulation area with a limited quantity of data and with a short measuring time, which allows the entire fundus to be observed during the treatment.

It is advantageous if the scanning device is provided with a rotating polygonal mirror for refracting the superimposed beam paths in a first co-ordinate and with an oscillating galvanometer mirror for refraction in a second co-ordinate.

In various embodiments of the invention, the optical modules for coupling and decoupling the measuring beam path in the therapy beam path can be arranged between the coagulation laser and a zoom lens, between the zoom lens and the refraction device or even beyond the refraction device.

Furthermore an acoustic signal transmitter can be provided in the information output unit which is triggered upon violation of a pre-selectable value

for the degree of reflection and/or the colour intensity at a measuring point.

It can often be advantageous if the arrangement for laser coagulation has a target laser for sighting the treatment area and if this is linked to the operation and control unit.

In a further advantageous embodiment, a source of radiation is provided which is designed both to emit a therapy beam and to emit a measuring beam whereby the measuring beam, in contrast to the therapy beam, has properties which cause no permanent tissue change; there is also a device for switching and/or changing the radiation from a therapy beam configuration to a measuring beam configuration and vice versa; furthermore a detector for recording the optical radiation issuing from the measuring points is connected via an evaluation unit and an information output unit to the operation and control unit and/or with the device for switching and/or changing the radiation configuration.

The advantage of this embodiment is that fewer modules (laser, control unit etc.) are required and the arrangement can consequently be effected with significantly less construction size.

At least one optical filter which can be introduced into the beam path can be provided as a device for switching and/or changing the radiation of the therapy beam configuration into the measuring beam configuration. If several filters are provided for alternate introduction, they should be arranged on a filter wheel.

Another conceivable device for switching and/or changing the radiation of

the therapy beam configuration into the measuring beam configuration is at least one power switch.

In this embodiment too there may also be devices for simultaneously striking several measuring points staggered in the depth of the tissue and means for evaluating the optical radiation issuing from the measuring points as per the embodiments described above.

The invention also relates to a procedure for operating the arrangement for laser coagulation as per the invention including its various embodiments.

Preferably, during a treatment, at least one optical measuring beam path is directed at at least one measuring point which is identical with the coagulation point or lies in its near surroundings, that the optical radiation issuing from the measuring point after the measuring beam strikes is detected and evaluated with regard to the physical and/or chemical properties of the tissue at the measuring point, that the result of this evaluation is subjected to a theoretical / actual comparison on the basis of a reference value and that a signal for aborting or continuing the treatment is derived and made effective from the result of this comparison.

The therapy laser can work with pulse durations in the region of microseconds or lower at a repetition frequency of 50 to 200 Hz.

The main advantage of this procedure is that objective evidence of the changes in tissue caused by the coagulation is possible during treatment and that a direct conclusion can be derived from this for aborting or continuing the

treatment. The procedure can be used in conjunction with new, tissue-protecting coagulation procedures. Furthermore, the procedure can be used in conjunction with photodynamic therapy in which the success or continuation of the treatment must likewise be evaluated using changes in the layers of the retina below the fundus surface.

Values of the reflectance of the tissue at the beginning and during and on repeated striking of the measuring point, on the change in reflectance during the course of the treatment can be ascertained from the optical radiation received from the measuring point by recording the intensity of the optical radiation issuing from the coagulation point or its near surroundings after being struck by the therapy beam and comparing it with a reference value. It is advantageous if several measuring points staggered in the depth of the tissue are struck simultaneously by the measuring beam and the optical radiation issuing from these measuring points is evaluated at staggered times from one another.

In this way the laser-induced changes of deep-lying retinal tissue layers can be proven and thus targeted coagulation is possible in these layers.

Alternatively to the evaluation of the reflectance and also at the same time, the colour intensity or the light wavelength of the optical radiation issuing from the measuring point can be recorded; the comparison with the reference value can provide information on the fluorescence behaviour of the tissue as well as information on changes in the behaviour at the measuring point of non-toxic photosensitisers which do not occur naturally in the body can be derived. Here

too it is possible to gain this information at the beginning of the treatment and during its progress.

This results in the advantage that the quantities of data to be recorded and also the necessary measuring time are limited to such an extent that it is possible to observe the entire fundus. As the fluorescence radiation originates in particular from deeper-lying retinal tissue layers, the evaluation of these deeper coagulation points is possible.

Using a separate source of radiation, the emission of the measuring beam can take place in accordance with and largely simultaneously with the emission of the therapy laser beam whereby the measuring beam is coupled to the therapy beam path and is refracted with the therapy beam path when the coagulation point is changed. The optical radiation issuing from the measuring points returns on the path of the measuring beam and is decoupled from the therapy beam path for evaluation.

Alternatively, however, it may be advantageous if the emission of the therapy and the measuring beam path takes place from the same source of radiation whereby it should be possible to switch this source of radiation in alternation from radiation suitable for therapy to radiation suitable for measurement and vice versa. To do this, the therapy laser can be switched after a limited time coagulation process (one or more therapy pulses) to an output suitable for measurement, at least one measuring pulse triggered after the switching which then detects and evaluates optical radiation issuing from the

measuring point and after evaluation, depending on the result, the treatment either aborted or the therapy laser switched to the output required for therapy and coagulation continued.

The switching of the therapy beam path to a measuring beam path can take place, for example, by switching the laser light wavelength using optical filters which can be swung into the beam path. It is also possible to provide power switches and to undertake the switching of the therapy beam path into a measuring beam path by switching the laser power.

The invention is described further hereinafter, by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is a representation of the principle of an arrangement in accordance with the present invention;

Fig. 2 shows a first embodiment of the arrangement in accordance with the present invention;

Fig. 3 shows a first variant of an interferometer for evaluation;

Fig. 4 shows a second variant of an interferometer for evaluation;

Fig. 5 shows an arrangement of the measuring beam round the therapy beam ;

Fig. 6 shows a second embodiment of the arrangement in accordance with the presnet invention; and

Fig. 7 shows an embodiment with a source of radiation which can be switched for therapy and measuring beam path.

Fig. 1 shows an arrangement for laser coagulation according to the present invention. A coagulation laser 1 for generating the therapy beam path 3 directed at the human eye 2, a zoom lens 4 for adjusting the diameter of the therapy beam, a refraction device 5 for locally changing the striking point of the therapy beam on the eye fundus and an operation and control unit 6 which is connected to the aforementioned modules are provided here. Besides these modules for therapeutic treatment, the coagulator has a measuring device 7 which has a source of radiation 8 for emitting a measuring beam path 9 (see fig. 2). Furthermore, there are optical modules for coupling and decoupling the measuring beam path 9 to the therapy beam path 3 (see also fig. 2 and fig. 6). Here in fig. 1, for example, the positions 10, 11 and 12 are indicated at which coupling and decoupling of the measuring beam path 9 to the therapy beam path 3 can be provided. Thus it is possible in different embodiments of the invention to arrange the optical modules for coupling and decoupling the measuring beam path 9 to the therapy beam path 3 at position 10 between the coagulation laser 1 and the zoom lens 4, at position 11 between the zoom lens 4 and the refraction device 5 or even at position 12 on the therapy beam path 3 beyond the refraction device 5. Furthermore, a fundus camera 13 and an illumination lens 14 are provided.

Fig. 2 shows a first embodiment of the arrangement as per the invention in which the measuring device 7 is formed as a device for optical short coherence interferometry for the depth-related recording of the current tissue

state. For this reason, an interferometric arrangement 15, a detector 16, an evaluation unit 17 and an information output unit 18 are provided in the measuring device 7 in addition to the source of radiation 8 for generating the measuring beam path 9 and are connected together as illustrated.

A feature of the interferometric arrangement 15 is that it is equipped with optical means for splitting the measuring beam path 9 into several individual beam paths (see fig. 3 and fig. 4).

In fig. 3, for example, the interferometric device 15 is equipped with three optical fibres 19, 20, 21. A super-luminescence diode is provided here as a source of radiation 8. The optical fibres 19, 20, 21 are separated spatially by means of branches so that there are three individual white-light interferometers with optical dividers 23, the reference arms 24 and the measuring arms 25. The length of the reference arms 24 can be varied using the common adjustable reflector 26. Furthermore, the individual reference arms 24 are designed with different lengths (indicated by loops in the reference arms 24). An optical divider 27 is provided as a module for coupling and decoupling the measuring beam path 9 (see fig. 2). The spatial separation of the optical fibres 19, 20, 21 and the entry point of the individual beam paths in the therapy beam path are, for example, set out in such a way geometrically that the three individual beam paths are arranged radially-symmetrically to the optical axis of the therapy beam path (see fig. 5).

Fig. 4 shows a second variant of the interferometric arrangement 15 which

has a lens 28 for splitting the measuring beam path 9 into (also by way of example) three individual beam paths. The individual beam paths strike different points from the lens; plane-parallel sheets 29, 30, 31 of varying thickness are arranged in the reference arms 32 of the individual beam paths which results in different optical routes for the individual reference arms. Here too the lengths of the reference arms 32 can be varied using a common adjustable reflector 33. The spatial separation of the individual beam paths and their entry points in the therapy beam path are set out in such a way geometrically that the three individual beam paths are arranged radially-symmetrically to the optical axis of the therapy beam path (see fig. 5).

The information output unit 18 has a display 34 for depth-related representation of information on the reflectance of the tissue at the measuring points (see fig. 2). The measuring device 7 is connected to the operation and control unit 6. The operation and control unit 6 is in turn formed in such a way that the binding of the measuring device into the overall function of the arrangement for laser coagulation is guaranteed e.g. by devices for starting the source of radiation 8, by a device for coupling the measured result (e.g. signal level of reflection) and a cut-out for the therapy laser for the purpose of aborting the treatment in the event of prescribed values being exceeded etc.

When operating the arrangement illustrated in fig. 2, the procedure is as follows:

Before beginning treatment, the treatment area is sighted using the fundus

camera 13 and the source of radiation 8 is then activated. A constant scanning process in the interferometric arrangement 15 through continuous adjustment of the reflector 26 in the z-axis is then triggered so as to vary the measuring depth.

The light issuing from the source of radiation 8 reaches the coagulation point or its near surroundings in the eye 2 via the optical dividers 23 (fig. 3 and fig. 4), the measuring arms 25 (fig. 3 and fig. 4) and then via the optical divider 27 for coupling in the therapy beam path (fig. 2), the zoom lens 4 and the refraction device 5, there it is refracted by the tissue, returns via the same path to the optical dividers 23 and is then diverted here into the reference arms 24.

Because of the long optical route of the corresponding reference arms, those reflection signals which have the shortest route in the measuring arm appear first at the detector 16. Then the signals with the longer measuring arms appear in sequence. In this way, every individual beam path in the interferometric arrangement 15 provides information from different depths of the retina whereby the adjustment position of the reflector 26 is a measure for a specific depth and the respective measuring point from which the information comes. Corresponding logical associations of depth-related information are then made in the evaluation unit from this relationship on the state of the tissue before the start of treatment at three points (seen in a cross section through the therapy laser beam 3 which are distributed radially-symmetrically round the coagulation point in accordance with the geometric arrangement of the individual

beam paths to the therapy laser beam 3.

The treatment with the therapy laser takes place once the initial state has been ascertained. The acquisition of depth-related information on the reflectance of the tissue is continued so that the tissue changes brought about by the effect of the coagulation can be established using the reflection signals. The intensity or signal level of the radiation issuing from the measuring point corresponds to the state in a specific depth of the retinal tissue structure because the reflectivity changes during coagulation.

The signal levels established are shown on the display 34 of the information output unit 18 and are thus made accessible to the operator. The latter decides on the basis of the signal level or shape whether to abort or continue the treatment., It is also conceivable that on reaching a prescribed signal level at a specific tissue depth for an acoustic or visual warning signal to be triggered which causes the operator to abort treatment. On appropriate further processing of the information signal, automatic abortion can also be caused e.g. by deactivating the therapy beam.

It is also possible to save the display image at the beginning of coagulation as the initial state and to show it as a comparison image during the treatment. The comparison is made using one or more further display images which are shown on the display during the progress of the treatment whereby a particularly clear indication of the change can take place by using an image processing device. The permissible signal levels for a specific depth can be

prescribed by the operator before treatment begins.

Naturally, arrangements are conceivable in which more than just the three individual beam paths used as an example are provided so that a greater number of measuring points are possible.

Fig. 6 shows a second embodiment of the arrangement as per the invention in which the scanning device 35 is provided as the refraction device for locally changing the striking point of the therapy beam path 3, which scanning device largely consists of a polygonal mirror 36 for refracting in the x-axis and a galvanometer mirror 37 for refracting in the y-axis laterally to the coagulation point. Furthermore, there is a lens module 45 to compensate for changes of focus and astigmatisms of the eye 2 under examination. In this example, the coupling and decoupling of the measuring beam path 9 in and out of the therapy beam path 3 takes place between the zoom lens 4 and the refraction device (position 11 in fig. 1). The measuring beam path 9 is therefore co-linearly superimposed on the therapy beam path 3.

In this case, besides the source of radiation 38, the measuring device 7 comprises a detector 39, an evaluation unit 40, an information output unit 41 and a filter unit 42 which is arranged in the beam path in front of the detector 39. The filter unit 42 is designed such that at least one optical filter 43 can be swung into the beam path, for example on a filter wheel.

The following procedure for operation is assigned to the arrangement described in fig. 6:

Before treatment starts, the source of radiation 38 is activated and the scanning device 35 set in operation. The measuring beam path 9 is scanned over the fundus by the movement of the polygonal mirror 36 and the galvanometer mirror 37; at the same time the intensity of the reflected light is recorded with the detector 39. If, for example, the rotation of the polygonal mirror 36 synchronises with the line frequency on the display 44 and the movement of the galvanometer mirror 37 is synchronous with the image repeat frequency, the output signal of the detector 39 prepared in the evaluation unit 40 can be indicated on the display 44. If the transmission wavelength of the filter 43 corresponds to the wavelength of the source of radiation 38, the fundus image is similarly displayed in black and white.

If the wavelength of the source of radiation 38 is in a range in which naturally-occurring fluophors in the tissue are incited to autofluorescence, such as lipofuscin at a wavelength of 512 nm, then after a further optical filter with a transmission wavelength tuned to the fluorescence is swung in, the autofluorescence of the tissue on the points of the retina at which the beam path is directed is recorded with the detector 39. The detected signal level can then be shown on the display 44 in the same way as described above.

If, with the filter unit 42, the optical filters are changed synchronously with the image construction frequency, the reflectivity and fluorescence are displayed following each other in time, but with a sufficiently high image repeat frequency, the human eye perceives only the superimposed fundus image. An embodiment

can, for example, display the fundus image and the fluorescence image in different colours. This can be done by changing the filter for different wavelength ranges relevant in this connection. The signal level received is characteristic for the state of the tissue at the beginning of the treatment.

After recording this initial state, treatment with the therapy laser takes place. The obtaining of laterally-related information on the autofluorescence and/or the reflectivity of the tissue is continued so that the tissue changes occurring as a result of the coagulation progress can be checked using the colour intensity established. The colour intensity or a corresponding signal level of the radiation issuing from the measuring points corresponds to the state of the retinal tissue structure at these points because the fluorescence behaviour changes during coagulation.

The established values are shown on the display 44 and thus made accessible to the operator. The latter decides on the basis of the level of the values whether to abort or continue treatment.

Here too it is possible to save the initial state and to show it as a comparison image during the treatment. The comparison is then made, for example, by subtracting the initial image from the respective displayed image of the fluorescence radiation whilst the fundus reflectivity for locating the coagulation point is displayed unchanged. Optionally it is possible to make a comparison using several fundus images.

Because of the common scanning device for the measuring and therapy

beam path, the control of the coagulation laser 1 and the selection of the areas on the fundus to be coagulated can be undertaken in such a way that the therapy laser can be activated and deactivated through temporal synchronisation with scanning device 35 or, depending on the location of the measuring beam path, using the image information on the fundus.

In both cases the operator marks the points to be coagulated on a first fundus image on the display 44 by the usual means e.g. mouse pointer. From the marked image co-ordinates (x, y) a specific swing angle of the polygonal mirror 36 and a specific position of the galvanometer mirror 37 are clearly mappable which in turn correspond to fixed delay times within the oscillation period T of the galvanometer mirror 37 or a rotation of the polygonal mirror 36. At each image repetition now the corresponding point on the fundus is coagulated as the coagulation laser 1 is activated with the delay time and image repeat frequency established.

Alternatively, the point for coagulation can be ascertained from the image correlation of successive fundus images. In this variant, it is advantageous if a possible eye movement is eliminated to the greatest possible extent.

With the arrangement shown in fig. 6 several fundus points can be coagulated during one scanning procedure so that the time taken for the entire coagulation procedure is reduced. Common to all approaches is the fact that clear evidence of the coagulation areas is facilitated which can be documented for the current and also for subsequent treatments.

Besides the options indicated thus far, it is conceivable that when a prescribed value is reached, an acoustic or visual warning signal is triggered which causes the operator to abort. On appropriate further processing of this signal, automatic abortion can also be caused e.g. by deactivating the therapy beam.

It is important that besides the embodiments of the arrangement described as per fig. 2 and fig. 6, further arrangement configurations for executing the procedure as per the invention are conceivable, above all both depth-related recording of the tissue status and the lateral recording of the autofluorescence behaviour can be provided for in an arrangement for laser coagulation as per the invention.

Fig. 7 shows an arrangement in which there is a source of radiation which is designed to emit both a therapy beam 3 and a measuring beam 9 whereby the measuring beam 9, in contrast to the therapy beam 3, has properties which do not cause any permanent tissue changes. A device 47 for switching and/or changing the radiation from a therapy beam configuration to a measuring beam configuration and vice versa is provided. A detector 39 is used for recording the optical radiation issuing from the measuring points; it is connected via an evaluation unit 40 and an information output unit 41 to the operation and control unit 6 and with the device 47 for switching and/or changing the radiation configuration.

It should be noted with the design that the permissible limits for laser

radiation laid down in VDE 0837 for the area of validity of Germany are not exceeded. For the design of the switching device 47 it is crucial, among other things, whether there is a point source of light or a broad source of light; the corresponding angle conditions and critical angles are also explained in the aforementioned VDI.

As a device 47 for switching and/or changing the radiation from a therapy beam configuration 3 to a measuring beam configuration 9, for example several optical filters arranged on a filter wheel and which can be introduced into the beam path to decrease the light wavelength to below the applicable limit.

The arrangement as per fig. 7 may be equipped as a device for simultaneously striking several measuring points staggered in the depth of the tissue as per the embodiments described above and with means for evaluating the optical radiation issuing from the measuring points, also as described above, so that a more detailed explanation here is superfluous and the description above can be referred to. This also applies to the procedure for operating this embodiment.

CLAIMS

1. An arrangement for the laser coagulation of layers of retina lying below the fundus surface with at least one source of radiation, comprising a refraction device for locally changing the striking point of the beam on the eye fundus ,

- means for striking the coagulation point and/or its near surroundings with an optical measuring beam during the treatment,
- the measuring beam having optical properties by means of which it can be reflected from the layers of retina and/or by means of which at least one fluophor occurring naturally and/or not occurring naturally in the tissue is incited, and
- at least one measuring device for the optical radiation issuing from the point struck, influenced by the measuring beam.

2. An arrangement for laser coagulation as claimed in claim 1, wherein a detector is provided in the measuring device to which an evaluation unit and an information output unit are connected for evaluating the reflectance and/or fluorescence behaviour of the tissue.

3. An arrangement for laser coagulation as claimed in claim 1 or 2, wherein the measuring device is connected to the operation and control unit.

4. An arrangement for the laser coagulation of layers of retina lying below the fundus surface as claimed in any of claims 1 to 3, wherein

- at least one separate source of radiation for emitting a measuring beam path to the coagulation point and/or its near surroundings which can be

reflected by retina layers is provided as the source of the measuring beam,

- optical modules are provided for coupling and decoupling the measuring beam path to the therapy beam path, and

- a device is provided for simultaneously striking several measuring points staggered in the depth of the tissue and/or near the coagulation point.

5. An arrangement for laser coagulation as claimed in claim 4, wherein the source of radiation is designed as a short coherent light source, the detector is tuned to the short coherent light source and an interferometer is provided in the beam path between the source of radiation and the detector whereby the interferometer is provided with at least one reference arm of variable length and at least one measuring arm partially lying in the eye.

6. An arrangement for laser coagulation as claimed in claim 5, wherein the measuring beam path is superimposed coaxially on the therapy beam path and a common refraction for changing the striking point on the eye fundus is effected by the refraction device.

7. An arrangement for laser coagulation as claimed in claim 5, wherein the interferometer is designed as a fibre interferometer in which the number of optical fibres corresponds to the number of measuring points planned, the individual optical fibres in the reference arms have different lengths and the individual optical fibres are assigned to different measuring points whereby the signals issuing from the measuring points must travel different length optical routes in the reference arm and thus temporally staggered detection of these

signals is guaranteed.

8. An arrangement for laser coagulation as claimed in claim 5, wherein the interferometer has a lens for splitting the measuring beam path into several individual beam paths whereby the number of individual beam paths corresponds to the number of measuring points planned, the individual beam paths emerge from different points on the lens and sheets of varying thickness are arranged plane-parrallel to the individual beam paths in the reference arms whereby the signals issuing from the measuring points must travel along different length optical routes and temporally staggered detection of these signals is guaranteed.

9. An arrangement for laser coagulation as claimed in claim 7 or 8, wherein the exit points of the individual beam paths are arranged radially-symmetrically to the therapy beam path and a common refraction is effected by the refraction device to change the striking point on the eye fundus.

10. An arrangement for laser coagulation as claimed in any of claims 4 to 9, wherein the information output unit has at least one display for indicating the degree of reflection on the fundus.

11. An arrangement for the laser coagulation of layers of retina lying below the fundus surface as claimed in any of claims 1 to 3, wherein

- at least one source of radiation is provided as a measuring beam source, the light wavelength of which incites at least one fluophor occurring naturally or not occurring naturally in the body,
- optical modules are provided for coupling and decoupling the measuring

beam path in the therapy beam path, and

- a detector and at least one optical filter which can be arranged in front of the detector are provided and tuned to the fluorescence wavelength of the fluophor.

12. An arrangement for laser coagulation as claimed in claim 11, wherein the optical filter which can be arranged in front of the detector is tuned to the autofluorescence wavelength of 512 nm of the body's own fluophor lipofuscin.

13. An arrangement for laser coagulation as claimed in claim 11 or 12, wherein a common scanning device is provided for lateral refraction of the measuring beam path and lateral refraction of the therapy beam path.

14. An arrangement for laser coagulation as claimed in claim 13, wherein the scanning device is provided with a rotating polygonal mirror for refracting the superimposed beam paths in a first co-ordinate and with an oscillating galvanometer mirror for refraction in a second co-ordinate.

15. An arrangement for laser coagulation as claimed in any of claims 11 to 14, wherein the information output unit has at least one display for indicating the colour intensity and/or the degree of reflection on the fundus.

16. An arrangement for laser coagulation as claimed in any of claims 4 to 15, wherein the optical modules for coupling and decoupling the measuring beam path in the therapy beam path are arranged in the beam path between the coagulation laser and a zoom lens.

17. An arrangement for laser coagulation as claimed in any of claims 4 to

15, wherein the optical modules for coupling and decoupling the measuring beam path in the therapy beam path are arranged in the beam path between a zoom lens and the refraction device.

18. An arrangement for laser coagulation as claimed in any of claims 4 to 15, wherein the optical modules for coupling and decoupling the measuring beam path in the therapy beam path are arranged in the beam path beyond the refraction device.

19. An arrangement for laser coagulation as claimed in any of claims 1 to 18, wherein the information output unit has an acoustic signal transmitter which is triggered upon violation of a pre-selectable value for the degree of reflection and/or the colour intensity.

20. An arrangement for laser coagulation as claimed in any of claims 1 to 19, wherein there is additionally a target laser for sighting the treatment area at the start of treatment and it is linked to the operation and control unit.

21. An arrangement for the laser coagulation of layers of retina lying below the fundus surface as claimed in claim 1, wherein

- a source of radiation is designed both to emit a therapy beam and to emit a measuring beam whereby the measuring beam, in contrast to the therapy beam, has properties which cause no permanent tissue change,
- a device is also provided for switching and/or changing the radiation from the therapy beam configuration to the measuring beam configuration and vice versa, and

- there is a detector for recording the optical radiation, influenced by the measuring beam and issuing from the measuring points and an evaluation unit and an information output unit are connected to the detector.

22. An arrangement for laser coagulation as claimed in claim 21, wherein the information output unit is connected to the operation and control unit and/or the device for switching and/or changing the beam.

23. An arrangement for laser coagulation as claimed in claim 21 or 22, wherein an optical filter which can be introduced into the beam path is provided as a device for switching and/or changing the radiation from the therapy beam configuration into the measuring beam configuration.

24. An arrangement for laser coagulation as claimed in any of claims 21 to 23, wherein at least one power switch is provided as a device for switching and/or changing the radiation from the therapy beam configuration into the measuring beam configuration.

25. An arrangement for laser coagulation as claimed in any of claims 21 to 24, wherein there is a device for simultaneously striking several measuring points staggered in the depth of the tissue as per claims 5 to 9.

26. A procedure for operating arrangements for laser coagulation as claimed in any of claims 1 to 26, wherein

- during a treatment session at least one measuring beam source is activated and an optical measuring beam path issuing from this measuring beam source is refracted, using optical modules, in the direction in which the therapy

beam is or was emitted

- the optical beam arising as a result of the measuring beam out of its direction of beam is detected and fed to an evaluation unit

- a comparison is made in the evaluation unit with stored reference values for the purpose of establishing the reflectance and/or fluorescence behaviour of the material at the striking point of the measuring beam and a resulting value is obtained from this comparison, and

- the resulting value is fed into an information output unit which emits a signal which can be perceived by the senses, which signal is dependent on the resulting value.

27. A procedure for operating arrangements for laser coagulation as claimed in claim 26, wherein an actual intensity value of the detected optical beam is fed to the evaluation unit and compared with a theoretical intensity value stored in the evaluation unit and in the event of the actual value exceeding the theoretical value, a message signal is forwarded to the information output unit whereupon the information output unit emits an acoustic warning signal.

28. A procedure for operating arrangements for laser coagulation as claimed in claim 26 or 27, wherein a colour intensity or light wavelength actual value of the detected optical beam is fed to the evaluation unit and compared with a colour intensity or light wavelength theoretical value stored in the evaluation unit which corresponds to the fluorescence behaviour of fluophors which do and/or do not occur naturally in the body and in the event of the actual value exceeding

the theoretical value, a message signal is forwarded to the information output unit whereupon the information output unit emits an acoustic warning signal.

29. A procedure for operating arrangements for laser coagulation as claimed in claim 26 or 27, wherein a colour intensity or light wavelength actual value of the detected optical beam is fed to the evaluation unit and compared with a colour intensity or light wavelength theoretical value stored in the evaluation unit which corresponds to the behaviour of non-toxic photosensitisers which do not occur naturally in the body after the effect of the therapy beam and in the event of the actual value exceeding the theoretical value, a message signal is forwarded to the information output unit whereupon the information output unit emits an acoustic warning signal.

30. A procedure for operating arrangements for laser coagulation as claimed in any of claims 26 to 29, wherein several points staggered in the depth of the tissue and/or points located to the side of the beam direction for the therapy beam are struck simultaneously or in succession by the measuring beam which in response detects optical radiation arising from the direction of beam of the measuring beam and feeds it to an evaluation unit and an evaluation as claimed in any of claims 27 to 29 is undertaken in the evaluation unit either simultaneously or temporally staggered through interim storage of measured values.

31. A procedure for operating arrangements for laser coagulation as claimed in claim 30, wherein the measuring beam is split into several individual beam

paths, the individual beam paths are grouped radially-symmetrically around the therapy beam path and thus the current state of the tissue is established on the one hand staggered in the depth of the tissue and on the other hand laterally at a distance from the coagulation point.

32. A procedure for operating arrangements for laser coagulation as claimed in any of claims 26 to 31, wherein using a separate source of radiation, the emission of the measuring beam takes place in accordance with and largely simultaneously with the emission of the therapy laser beam whereby the measuring beam is coupled to the therapy beam path, is refracted with the therapy beam path when the coagulation point is changed, the optical radiation issuing from the measuring points returns on the path of the measuring beam and is decoupled from the therapy beam path for evaluation.

33. A procedure for operating arrangements for laser coagulation as claimed in any claims 26 to 31, wherein the therapy and the measuring beam paths are emitted from the same source of radiation.

34. A procedure for operating arrangements for laser coagulation as claimed in claim 33, wherein the source of radiation is initially operated with an output and/or wavelength necessary for the therapy, the radiation source is switched after a limited time coagulation process to an output and/or wavelength suitable for measurement, at least one measuring pulse is triggered after the switching which then detects and evaluates optical radiation issuing from the measuring point after the measuring beam strikes and after evaluation, depending on the

result, the treatment is either aborted or the therapy laser is switched to the output and/or wavelength required for therapy and coagulation continued.

35. A procedure for operating arrangements for laser coagulation as claimed in any of claims 26 to 34, wherein the therapy laser is controlled using the information gained with the measurement.

36. An arrangement for the laser coagulation of layers of retina lying below the fundus surface with at least one source of radiation, substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

37. A procedure for operating arrangements for laser coagulation as claimed in claim 1, substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): A5R (REWL); G1A(ABGX, ACEX, ACJX, ADMX, AAMX)

Int Cl (Ed.6): A61F 9/00 & 9/007

Other: Online: WPI, INSPEC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage			Relevant to claims
Y	US 5157428	(SKLAR et al)	See whole document	1-3
Y	US 4758081	(BARNES)	See col 2 lines 1-14 & col 3 lines 40-55	1-3,11,13, 15,21 & 22
Y	US 4741612	(BIRNGRUBER et al)	See col 1 lines 16-36	1-3
Y	WO 93/16631	(PHOENIX LASER)	See pages 41 & 55 in particular	1-3,11,13, 15,21 & 22

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